[Chicago-Kent Law Review](https://scholarship.kentlaw.iit.edu/cklawreview)

Volume 80
Issue 3 *Symposium: Must We Choose Between Rationality and Irrationality?*

Article 9

June 2005

Neuroeconomics and Rationality

Terrence Chorvat

Kevin McCabe

Recommended Citation

Terrence Chorvat & Kevin McCabe, *Neuroeconomics and Rationality*, 80 Chi.-Kent L. Rev. 1235 (2005).
Available at: https://scholarship.kentlaw.iit.edu/cklawreview/vol80/iss3/9

NEUROECONOMICS AND RATIONALITY

TERRENCE CHORVAT* & KEVIN MCCABE**

INTRODUCTION

A greater understanding of human thought processes can aid us in the study of law in at least two ways. First, it can help us to better predict the effect of a particular legal regime on behavior, which is of primary importance in deciding on the proper structure of a legal regime. Second, it can also help us to understand what it means to improve the welfare of the members of society. Just as all human decision making involves making estimates concerning optimality, so it must be for the government and its decision making. Neuroscience can and should inform these decisions.

In recent years, we have learned a great deal about human decision making. Not only has there been an enormous amount of behavioral research but there has also been a large and increasing amount of research on the neural mechanisms involved in human decision making. It is difficult to overstate the importance of this research to our understanding of human decision making. Milton Friedman once suggested that, as we formulate models, the truth of the assumptions does not matter if the model can predict behavior reasonably correctly,[1] but, as Herbert Simon pointed out, this would only be a good way of thinking if we do not have microscopes.[2] Effectively, we do now have microscopes that we can use to examine the mechanisms of human decision making.

I. HUMAN DECISION MAKING AND RATIONALITY

One of the key problems for both economics and for the application of economics to legal scholarship is the extent and the nature of rationality exhibited by economic actors. This is one of the largest areas of disagreement between adherents of traditional law and economics and the propo-

* Associate Professor of Law, George Mason University. Professor Chorvat would like to thank the Laurence Cranberg Foundation and the Law and Economics Center for its support.

** Professor of Economics and Law, George Mason University, Director, the Center for Law and Neuroeconomics. The authors would like to thank Elizabeth Chorvat for her helpful comments.

1. MILTON FRIEDMAN, ESSAYS IN POSITIVE ECONOMICS (1953).

2. Herbert A. Simon, *Problems of Methodology—Discussion*, 53 AM. ECON. REV. 229, 229–30 (1963).

nents of what is often referred to as behavioral law and economics.[3] This Article discusses what some of the most recent research in experimental economics, as well as research in neurology and the relatively new discipline of neuroeconomics, can tell us about rationality and the importance of rationality for legal scholarship.

The notion of rationality creates many problems for economics and legal scholarship. First, it is not immediately obvious what it means to be rational.[4] A reasonable definition would be a decision process that results in the selection of the "best" method of accomplishing a goal. Alternatively, almost any decision process that is rule-based can be argued to be rational.[5] In addition, rationality can be applied to many aspects of decision making. For example, rationality can be applied to belief, which forms a key part of choice behavior. If a decision maker ignores some pertinent evidence in forming the relevant beliefs, then one might term these beliefs irrational. On the other hand, one could argue that an action could be rational given the beliefs of the individual, although the model-building process is faulty.

The notion of rational belief is important to understanding legal issues in part because reasoning about social problems generally must be highly opportunistic. We rarely have direct answers to those questions that we would most like answered. We can only imperfectly understand human behavior and the range of potential responses to particular legal regimes. Therefore, we can only make probabilistic predictions about the behavior that will result under differing combinations of legal rules.[6] At best, we can claim that the process by which those predictions are made may be more or less rational.

Another inherent problem that rationality poses for legal scholarship is how to address the fact that the degree of rationality found in the population is heterogeneous. Should we treat all individuals as equally rational? If most, but not all, individuals are generally rational, what does this mean in terms of the presumptions policymakers and judges should make? No

3. *See generally* Colin F. Camerer & George Loewenstein, *Behavioral Economics: Past, Present, Future*, *in* ADVANCES IN BEHAVIORAL ECONOMICS 3–4 (Colin F. Camerer et al. eds., 2004).

4. One might view rationality to include the selection of the optimal neural mechanism, which is discussed *infra* at Part II(c).

5. Such a process can be said to maximize conformity with the rules on which it is based. *See generally* GARY S. BECKER, THE ECONOMIC APPROACH TO HUMAN BEHAVIOR (1976).

6. A good example of this is the development of the hub and spoke system as a result of the deregulation of airlines in the 1970s, because the airport operators did not charge a higher fee for increased airport congestions. *See* Vernon L. Smith, *Constructivist and Ecological Rationality in Economics*, 93 AM. ECON. REV. 465, 472 (2003).

agent, either individual or institutional, possesses all the relevant information for making decisions.[7] Therefore, decisions must be made in the absence of perfect information. To what extent should we treat such agents as rational if the level of information varies and, consequently, the decision-making processes vary?

A. *Modeling Rationality*

Those models relevant to law will generally have as their inputs environmental variables and have as their outputs the behavior of individuals, groups of individuals, or institutions. Therefore, one might argue that research into neurobiology and neuroeconomics will only give us information that in some sense we could have learned from psychological or standard economic research. This argument, however, reflects a faulty understanding of the model-creating process. It is very likely that by understanding the neural mechanisms of decision making we will be able to create better models of the interaction between the environment and human behavior. Proceeding without the insights of neurobiology and neuroeconomics would be rather like attempting to model the behavior of a car without understanding the intricacies of the internal combustion engine. As an understanding of the oxygen requirements of the combustion process will serve to explain why cars do not perform as well at high altitude or on cold days, research in neurobiology and neuroeconomics will help us resolve many conflicts over the nature of human behavior, such as the extent to which, as well as the ways in which, humans are rational (which might change from individual to individual as well as society to society).

One can argue that law and economics is in fact a form of applied psychology in that it seeks to apply a particular model of human behavior (i.e., rational choice) to solve problems. The methodology of law and economics has helped us answer a number of important questions because it is able to form precise models that create falsifiable predictions. The results from testing earlier predictions are then used to alter the models to cause them to come into greater conformity with observed behavior, both by revealing the likely result of particular policy prescriptions and also by modifying our understanding of what an optimal society might be. Here, the

7. For example, we do not know if the sun will explode tomorrow or if the earth's magnetic field will dissipate more quickly than anticipated, but both of these events would have a dramatic effect on our future plans.

relatively new discipline of hedonic psychology can play an important role.[8]

Although the premises behind economic analysis' normative conclusions can of course be questioned, it is difficult to question the usefulness of economic analysis in the discussion of any number of diverse issues such as optimal tax policy, the drug legalization debate, "three strikes" laws, or in the discussion of any form of economic regulation such as antitrust and securities laws.

It is difficult to argue that there is no correlation between behavior and well-being. Some of the utility of economic analysis derives from the fact that it does appear that for many purposes individuals can be considered rational.[9] Recall that rationality can be defined as selecting the best method of accomplishing a specified goal. Clearly, from an evolutionary perspective, pleasure and pain exist to motivate human behavior; but, as research in cognitive neuroscience has shown, these are not the only systems which influence behavior, and, therefore, it should not be surprising to us that some behavior appears irrational.[10] One of the hallmarks of rational decision making is the notion that preferences, whatever they may be, are stable.[11] If choices are random, it may be difficult to refer to these choices as guided by preferences.[12]

A common defense of the rationality assumption has been that a wide variety of behavior can be explained by models based on this assumption. However, many academic commentators have discussed how predictions of the standard economic model do not seem to be borne out in either experiments with individuals or in the econometric data.[13] A number of academics have argued that, in fact, individuals *systematically* deviate from standard notions of rationality.[14] This work is sometimes referred to as behavioral economics but is more accurately thought of as economics with an empirical focus. Note that many of these examples cited in this literature

8. *See generally* WELL-BEING: THE FOUNDATIONS OF HEDONIC PSYCHOLOGY (Daniel Kahneman et al. eds., 1999).

9. *See* Alvin E. Roth, *Adaptive Behaviour and Strategic Rationality: Evidence from the Laboratory and the Field, in* THE RATIONAL FOUNDATIONS OF ECONOMIC BEHAVIOUR 225, 225 (Kenneth J. Arrow et al. eds., 1996).

10. *See generally* Bartley G. Hoebel et al., *Neural Systems for Reinforcement and Inhibition of Behavior: Relevance to Eating, Addiction, and Depression, in* WELL-BEING: THE FOUNDATIONS OF HEDONIC PSYCHOLOGY, *supra* note 8, at 558.

11. *See generally* ANDREU MAS-COLELL ET AL., MICROECONOMIC THEORY (1995).

12. *See* Gary S. Becker, *Irrational Behavior and Economic Theory*, 70 J. POL. ECON. 1 (1962).

13. *See* Camerer & Loewenstein, *supra* note 3.

14. For an early example of this work, see Kenneth O. May, *Intransitivity, Utility, and the Aggregation of Preference Patterns*, 22 ECONOMETRICA 1 (1954).

are not merely violations of expected utility in a manner similar to the Allais paradox or the Ellsberg paradox, which can be rationalized through the use of complex risk preferences,[15] but rather violate notions of rationality altogether. In the face of such evidence, psychologists such as Amos Tversky have questioned why economists have such reluctance to give up the rationality hypothesis in the face of such strong evidence.[16]

Many economists argue that we can gain some level of confidence for the view that the realism of the assumptions does not matter from the fact that often other disciplines such as physics make unrealistic assumptions.[17] Indeed, if this is the case, reference to other disciplines might indicate how these models might be useful in a variety of ways. Other disciplines often use mathematical forms of optimization even where almost no one is hypothesizing that some actual choice process is occurring. Physicists often use optimization methods in studying physical systems yet, except for a very small fringe group, physicists do not assume that the physical systems at issue are in any real sense part of the decision-making process.[18] Economists have long acknowledged that rational models are not the only ways in which individuals exhibit choice behavior. In essence, many macroeconomic models actually assume certain levels of irrationality.[19]

Economists have also argued that the rationality assumption is reasonable even though it cannot explain all human behavior, because it can be used to predict much of human behavior. This was the form of Alvin Roth's response to Amos Tversky's argument against the rationality hypothesis. Roth argues that the applicability of rational models depends on the level of analysis required for the problem.[20] Roth divided the levels of analysis into standard economic models (further subdivided into risk-neutral models and expected utility models), psychological models, and neurobiological models. One could further divide neurobiological models into those models that address the interactions between larger neural mechanisms (for example, certain models address how the dorsolateral

15. See description of the Allais paradox and the Ellsberg paradox in Terrence Chorvat, *Taxing Utility*, J. SOCIOECONOMICS (forthcoming 2005) (manuscript at 14–16), *available at* http://law.bepress.com/cgi/viewcontent.cgi?article=1016&context=gmulps at 14–16.

16. Amos Tversky, *Rational Theory and Constructive Choice*, *in* THE RATIONAL FOUNDATIONS OF ECONOMIC BEHAVIOUR, *supra* note 9, at 185.

17. FRIEDMAN, *supra* note 1, at 30–32.

18. *See* PAUL A. SAMUELSON, FOUNDATIONS OF ECONOMIC ANALYSIS (enlarged ed. 1983). See RICHARD P. FEYNMAN, THE FEYNMAN LECTURES ON PHYSICS 26-3 (1963) for a description of the least time principle.

19. Kenneth J. Arrow, *Rationality of Self and Others in an Economic System*, 59 J. BUS. S385, S386 (1986).

20. Roth, *supra* note 9.

prefrontal cortex appears to process data in a manner different than the insula cortex)[21] versus biochemical models (for example, certain models address how higher levels of serotonin lead to less impulsive behavior because of the lower levels of activation in various cortical neural circuits).[22] Research on these two types of neurobiological models is of a different sort and, while clearly connected, yields different types of results. The rationality assumption would seem to be more applicable to the models that involve larger scale process (e.g., the agent as a whole) than to those models that address electrochemical changes in the cells that make up the brain.

1. The Risk Neutral Model

Using Roth's terminology, the first category of models of human economic behavior are the risk neutral model. Risk neutral models posit that individuals act so as to maximize the expected value of their wealth. This may be viewed as the very first model for utility theory, as it was designed to explain the value of various gambles and why individuals are likely to take certain gambles and not take other gambles. This theory was formulated by Pierre de Fermat and Blaise Pascal in the late 1600s. Soon after its formation, problems with the model were discovered.[23] The most famous of these problems is known as the St. Petersburg Paradox, which was "solved" by Daniel Bernoulli through the creation of an antecedent of expected utility theory.[24]

2. The Expected Utility Model

As a result of further developments of Bernoulli's ideas, a new model of human behavior—the expected utility model—became the standard model for economic analysis. This second family of models has more explanatory power regarding behavior than the first. For example, it can explain why individuals purchase insurance and why stocks have a higher return than bonds.[25] Models based on the assumptions of expected utility

21. *See* Alan G. Sanfey et al., *The Neural Basis of Economic Decision-Making in the Ultimatum Game*, 300 SCIENCE 1755 (2003).

22. JOSEPH LEDOUX, SYNAPTIC SELF: HOW OUR BRAINS BECOME WHO WE ARE 286–88 (2002).

23. *See* Terrence R. Chorvat, *Ambiguity and Income Taxation*, 23 CARDOZO L. REV. 617, 620–22 (2002).

24. Daniel Bernoulli, *Specimen Theoriae Novae de Mensura Sortis*, 5 COMMENTARII ACADEMIAE SCIENTIARUM IMPERIALIS PETROPOLITANAE 175 (1738), *translated in Exposition of a New Theory on the Measurement of Risk*, 22 ECONOMETRICA 23 (1954). The St. Petersburg paradox involves a gamble with an infinite expected value for which individuals are only willing to pay a modest amount. For a description of the St. Petersburg paradox, see Chorvat, *supra* note 23, at 620–22.

25. Roth, *supra* note 9.

theory have also been used to explain the pricing of assets, both real and financial. These models form the backbone of what can be referred to as both neoclassical economics and traditional law and economics. These theories form the basis for game theory, price theory, and the rational expectations models of macroeconomics.[26] Interestingly, while the more recent expected utility models are able to explain a greater variety of behavior, there still remain many applications of risk-neutral models in economics. For example, many argue that corporate managers should be essentially risk-neutral in their decision making, because shareholders can diversify away most of the idiosyncratic risk of any corporation.[27] Furthermore, some economists have argued that the government should essentially act in a risk-neutral manner.[28]

3. "Almost Rational" Models

Another type of model for human behavior that has been developed recently can be described as "almost rational."[29] These models resemble expected utility models in many respects but add assumptions, such as that individuals may have more complicated risk preferences and may not ignore sunk costs. In many versions of models, the reference points of the agents significantly affected the predicted behavior. One can still call such persons rational although they may have seemingly complicated views of risk.[30] These models include a variety of non-expected utility theories.[31]

4. Psychological Models

Another family of behavioral models might be described as psychological models. These models do not posit stable preferences functions, but rather a set of psychological processes that interact with the environment to create behavior.[32] One could argue in some sense that even these models constitute examples of economic models as well. The actors in these models are various psychological needs, instead of individuals of standard eco-

26. ROBERT E. LUCAS, JR., MODELS OF BUSINESS CYCLES (1987).

27. Roth, *supra* note 9.

28. Kenneth J. Arrow & Robert C. Lind, *Uncertainty and the Evaluation of Public Investment Decisions*, 60 AM. ECON. REV. 364, 364 (1970).

29. Alvin E. Roth, *Bargaining Experiments*, *in* THE HANDBOOK OF EXPERIMENTAL ECONOMICS 349 (John H. Kagel & Alvin E. Roth eds., 1995).

30. Matthew Rabin & Richard H. Thaler, *Anomalies: Risk Aversion*, 15 J. ECON. PERSPS. 219, 221–22 (2001).

31. For a description of these models see Colin Camerer, *Individual Decision-Making*, *in* THE HANDBOOK OF EXPERIMENTAL ECONOMICS, *supra* note 29, at 626–51.

32. Haim Levy & Marshall Sarnat, *Diversification, Portfolio Analysis and the Uneasy Case for Conglomerate Mergers*, 25 J. FIN. 795 (1970).

nomic models, and the ultimate action taken by the individual depends on the internal dynamic between these psychological needs. One can analogize these models to economic theories of group interactions. These models allow for preference reversals, just as social choice theory shows that group decision making will not always lead to consistent choices.[33] Even these psychological models essentially assume some rationality principle, in that there is some choice process behind the various psychological processes. To the extent that this choice process is rule-based, it too can be rationalized.

5. Neurobiological Models

The final type of model for human behavior that we should consider is the neurobiological model. These models are based not on preferences or psychological processes, but rather on the physical processes of decision making. In some sense, these represent the height of rationalizable models, because physical processes follow deterministic rules until one arrives at the quantum level.[34] There is a variety of these types of models. Two prominent types of these models are: first, models that address the interactions between different brain regions, and, second, models that address the underlying neurochemistry of decisions. Much of the research in this field is conducted on particular areas of brain activation during decision making, as well as research on a more microscopic level revealing the changes to neurons and glial cells that occur as the result of certain events in the brain. Carried to their logical extreme, for example, these models might reveal that the reason a particular decision was made was a change in the membrane permeability in certain neuronal and glial cells.

Currently, it seems rather far-fetched for economists to calculate the effects of a 20% versus 25% income tax rate based on neuronal membrane permeability in various regions of the brain. Although such models might eventually attain this level of accuracy, nonetheless, at least currently, these results would essentially be impractical and would include too many degrees of freedom to yield helpful predictions.

6. Summary

It is indeed important to understand the level of rationality appropriate to explain the particular behavior at issue. One of the keys of science is the

33. DAVID M. KREPS, A COURSE IN MICROECONOMIC THEORY 174–81 (1990).

34. For a discussion of the impact of quantum mechanics on the determinism of the classical Newtonian physics, see FEYNMAN, *supra* note 18, at 37-10 to 37-11.

creation of falsifiable hypotheses. If a model can always accommodate all factual evidence, then it is nonfalsifiable and therefore nonscientific.[35] Because there are so many differing models for human behavior, a key problem is that one can always *ex post* choose the model to best fit the data rather than *ex ante* predict what the data should be. For example, if individuals behave rationally, we might use rational models; if they do not, we might use psychological or neurobiological models. Picking and choosing models *ex post* in this fashion is unsatisfactory. Rather, we should develop a *meta* model for deciding when to use rational models, psychological models, or whatever models we eventually develop. This is particularly true given that, in some sense, psychological and neurobiological models are more in the nature of catalogues of decision processes rather than overarching models of decision making. Future models that incorporate neurobiological research must be able to predict the behaviors that are more likely to be better approximated by rational models and those that are more likely to be better approximated by nonrational models. The models should both explain the diversity of human behavior and yet predict what will commonly happen.

II. ECOLOGICAL VERSUS CONSTRUCTIVIST RATIONALITY

Another problem with the argument against using rational models as predictive of human behavior is that opponents assume only one type of rationality, commonly referred to as constructivist rationality. Constructivist rationality is based on the rationality utilized by René Descartes in trying to deduce morality and rules of decision making from a small set of first principles.[36] One can see this type of rationality played out to a great extent in modern game theory, which assumes a relatively small set of axioms about the utility of the players and from that deduces an enormous number of findings of great complexity.[37]

But this is not the only form of rationality. It is important to distinguish constructivist rationality from ecological rationality. Ecological rationality is not rational in the sense that it concerns a set of decision rules that are able to predict what should happen in each situation, or that it will *necessarily* give the optimal path to the solution that we can see would

35. KARL R. POPPER, LOGIK DER FORSCHUNG (1934), *translated in* THE LOGIC OF SCIENTIFIC DISCOVERY 40–41 (1959).

36. *See generally* RENÉ DESCARTES, DISCOURS DE LA MÉTHODE POUR BIEN CONDUIRE SA RAISON ET CHERCHER LA VÉRITÉ DANS LES SCIENCES (Louis Liard ed., 1960).

37. *See generally* ROGER B. MYERSON, GAME THEORY: ANALYSIS OF CONFLICT (1997).

have been optimal *ex post*.[38] Rather ecological rationality results in optimal decision rules given the costs of making the decision and the neurological mechanisms available to the decision maker. This is related to constrained optimization, under which the cost of obtaining new information is included in the decision constraints. As with bounded rationality, the decision rules created by ecological rationality may not be rational for all possible states of the world, but they might be rational in states of the world that are likely to occur. This view is more likely to reflect neurological reality than are constructivist notions of rationality.

Not only is individual decision making more likely of an ecological nature, but one can argue that governmental decision making should be of this variety as well. Just as individuals who are able to learn about their environment are more likely to survive, institutions that are able to adapt and change are more likely to survive, and, therefore, over time are more likely to comprise a higher proportion of the institutions we see.[39] Even though no one person may understand why an institution has survived, it will have survived because it was better able to adapt to situations than other institutions, just as crocodiles do not understand why their kind has survived since before the time of the dinosaurs.

A. *Game Theory and Constructivist Rationality*

Decision theory is the study of how individuals make decisions.[40] When these decisions are strategic—that is, where the behavior of one agent affects decisions made by others—this study is called game theory.[41] In classical game theory, games are employed as a metaphor for strategic decision making by economic actors in situations where choices by one affect decisions by the others. One can argue that mathematical decision theory and mathematical game theory give the normatively "correct" answers to problems. However, in real world situations the "right" answers might depend on the actual actions of others who may not be game theorists, and, therefore, it is important also to understand the decisions humans actually make, not just those they "should" make.

38. Smith, *supra* note 6, at 469–71.

39. Armen A. Alchian, *Uncertainty, Evolution, and Economic Theory*, 58 J. POL. ECON. 211 (1950).

40. Peter Gärdenfors & Nils-Eric Sahlin, *Introduction: Bayesian Decision Theory: Foundations and Problems*, *in* DECISION, PROBABILITY, AND UTILITY: SELECTED READING 1, 1–4 (Peter Gärdenfors & Nils-Eric Sahlin eds., 1988).

41. KREPS, *supra* note 33, at 355.

Very commonly individuals do not behave as predicted by game theory.[42] This may be for reasons of cognitive limitation, or it may be because of other reasons that are more difficult to describe but involve social cognition and group dynamics.

B. Adaptive Learning

One of the most common tests of rationality is the ability to avoid what is referred to as a "Dutch book." A "Dutch book" is a mechanism by which a series of bargains are placed before a subject, and while each of the bargains is favorable to the subject, yet, at the end of the series, the subject has no money and nothing to show for himself.[43] Because we do not observe many Dutch books in the real world, nor does it seem that rational persons would permit a Dutch book to operate against them, this has become one of the standard tests of rationality. It can be demonstrated that, were a robot endowed with many of the standard utility functions of human beings, it would be subject to the Dutch book argument.[44] Why then do we not we see Dutch books in the real world?

Dutch books do not work because people learn not to let others take advantage of them.[45] One can see how learning-based models may be both better predictors of behavior than expected utility models and in some sense are to be preferred over the strict expected utility models. For example, it may be optimal for a group of individuals to allow each member to experiment individually and then after some period of time the members of the group could begin to imitate others who have succeeded.[46] From an evolutionary perspective, one can see how agents who adopt the imitation of the success of others as a basic strategy might succeed in wide variety of environments. This concept is connected with the notion that we do not need to understand every aspect of a principle in order to understand how it can be used.[47]

42. *See generally* COLIN F. CAMERER, BEHAVIORAL GAME THEORY: EXPERIMENTS IN STRATEGIC INTERACTION (2003).

43. *See* Menahem E. Yaari, *On the Role of "Dutch Books" in the Theory of Choice Under Risk*, *in* FRONTIERS OF RESEARCH IN ECONOMIC THEORY: THE NANCY L. SCHWARTZ MEMORIAL LECTURES, 1983–1997, at 33, 34 (Donald P. Jacobs et al. eds., 1998).

44. *See* Rabin & Thaler, *supra* note 30, at 227–29.

45. *Id.* at 227.

46. Roth, *supra* note 9, at 264.

47. *See* FEYNMAN, *supra* note 18, at 4-1.

Therefore, the experiments discussed as disproving rationality might be better thought of as disproving constructivist rationality.[48] With some introspection, we should not be surprised that individuals who are not trained as statisticians will make significant mistakes in their decisions. This does not mean that individuals cannot make correct decisions about questions that involve statistical inference, but rather the method by which these decisions are made may not reach the normatively correct answer in all cases.

Both behavioral and neurobiological research indicates that learning occurs in very complex frameworks, not merely simple Hebbian association or "selectionist" models.[49] Explanations of human decision making based on evolutionary psychology are fascinating and helpful, but, ultimately, scientific knowledge and models must flow from experimental or other empirical evidence, rather than introspection alone.

Focusing on ecological rationality as opposed to constructivist rationality may cause us to realize that there is no real substitute for the careful study of natural environments. Were economists to attempt to understand market behavior without studying real behavior (for example, in the case of the St. Petersburg paradox[50] and insurance), we might not have been inspired to create the expected utility models in place of the expected value models. Economic models generally assume tastes that are both exogenous and stable.[51] We assume that when choices are made that are different than previous choices, rationality has been violated. It is of course always possible that preferences have changed. If, however, we were to allow preference changes to commonly enter into our explanations, we would almost never be able to falsify a theory, thus removing it from a Popperian notion of science.[52] Without a good theory of how tastes change, we cannot allow these considerations to enter the models.

Psychological models and neurobiological models might be particularly helpful in enabling us to elucidate how tastes are formed. This may help to explain paradoxes such as Tversky's Williams-Sonoma catalog example (the existence of a third alternative will cause more purchases of

48. For example, the experiments conducted by May, *supra* note 14, do not necessarily disprove some type of ecological rationality.

49. For a discussion of Hebbian models, see LEDOUX, *supra* note 22, at 80–81.

50. Bernoulli, *supra* note 24, at 29–30.

51. We say this noting the exception of models such as Becker's, see Gary S. Becker et al., *Rational Addiction and the Effect of Price on Consumption*, 81 AM. ECON. REV. 237 (1991), and derivatives of it.

52. POPPER, *supra* note 35, at 92.

one of two previously available alternatives).[53] Research in both psychology and neurology likely will be very helpful in explaining the effectiveness of advertising, as well as phenomena such as the degree of trust and trustworthiness of members of different societies. One reasonable hypothesis about the behavior of subjects in experiments in different societies is that we are seeing artifacts of their behavior in the world. This notion is buoyed up by recent research which seems to indicate that members of different societies often adopt different strategies in simple experimental situations.[54] However, one must consider that one of the possible effects of the double blind study might be to make clear to the subjects that the standard rules of society do not apply.

Many researchers in human behavior and biology have adopted an approach, referred to as cognitive neuroscience, that integrates psychology, biochemistry, neurology, evolutionary biology, and related sciences in order to further our understanding of human behavior.[55] One problem with such interdisciplinary efforts is coordinating the different methods of inquiry. Grossly oversimplifying, biological sciences follow more of a cataloging approach (e.g., this behavior is correlated with this neural mechanism), whereas economics attempts to create models that predict a wide variety of behavior with very simple models.

One of the problems with the cataloging method, which has been the dominant paradigm in the neurological research, is that it fails to predict new behavior. It can be argued that the opposite problem applies to economics' assumption of rationality. The rationality hypothesis is quite resilient when there is only a finite amount of data (as long as it complies with the weak axiom of revealed preference).[56] One can analogize some of the results of economic analysis to the famous experiments in which split-brain patients were able to rationalize what they did not understand, even while it was clear that the rationalization was incorrect.[57]

It has long been hypothesized that biological mechanisms can have direct control of our behavior in particular areas.[58] Merely understanding that there may be genetic influences on behavior, however, does not tell us how this behavior is created, nor how the mechanism utilized for one problem

53. Tversky, *supra* note 16, at 194.

54. Joseph Henrich et al., *In Search of Homo Economicus: Behavioral Experiments in 15 Small-Scale Societies*, 91 AM. ECON. REV. 73 (2001).

55. *See generally* MICHAEL S. GAZZANIGA ET AL., COGNITIVE NEUROSCIENCE: THE BIOLOGY OF THE MIND (2d ed. 2002).

56. MAS-COLELL ET AL., *supra* note 11, at 12.

57. GAZZANIGA ET AL., *supra* note 55, at 436–37.

58. *Id.* at 62–95.

may influence other types of behavior. Cognitive neuroscience can help us to resolve these questions by directly examining the neural mechanisms involved. As pointed out by Joseph LeDoux, the link between the brain and behavior is much, much stronger than the link between genetics and behavior.[59]

C. *Ecological Rationality and Neurological Mechanisms*

For a variety of reasons, including those discussed above, constructivist rationality seems unlikely as a paradigm of behavior, particularly given what we know about neurological mechanisms. Rather, constructivist rationality seems based on forethought about future states with precise payoffs. Neurological research shows us that there are many different regions of the brain that process information differently. This section will discuss some areas of research that explore how this compartmentalization occurs. In particular, it will examine research that examines differences between conscious and unconscious processes and differences between personal and impersonal decisions. Finally, it reviews some interesting work on the ultimatum game.

1. The Cost of Conscious Awareness

Neurological research indicates that cognition is a costly resource. Because brains are finite and because there is a payoff to increasing our understanding of the world, the constraints on the capabilities of our brains can seriously affect the manner in which functions are performed.[60] Most of the brain does not seem to be directly involved in conscious processes.[61] Two key questions are, then, how does the brain decide which problems it will address and, once this selection has been made, what neural mechanisms are used to solve the problem? It appears that the answers are governed by rules similar to those that economists and operations research specialists use in their optimization calculations. In particular, it appears that the brain consists of modules that solve particular kinds of problems.[62] There are clear evolutionary advantages to this. Individuals are confronted with a finite, although very large, set of problems. Solving the specific problems presented and having tissues structured for solving those prob-

59. LEDOUX, *supra* note 22, at 3–5.

60. Herbert A. Simon, *Bounded Rationality*, *in* THE NEW PALGRAVE: A DICTIONARY OF ECONOMICS 266–67 (John Eatwell et al. eds., 1987).

61. GAZZANIGA ET AL., *supra* note 55, at 660–68.

62. Jacqueline N. Wood & Jordan Grafman, *Human Prefrontal Cortex: Processing and Representational Perspectives*, 4 NATURE REVIEWS NEUROSCIENCE 139 (2003).

lems would be more efficient than having general purpose tissues which would likely be more costly and not as well adapted.[63]

Because there are a nearly infinite number of stimuli in the world at any given time, in order to focus on any object, we must decide to ignore some stimuli and focus on others. Even after we are aware of a "problem," we have many potential mechanisms to use to address the issues raised. For example, we may react impulsively or we may calculate the optimal decision. Research in cognitive neuroscience suggests that different methods of problem solving are located in different parts of the brain. An example of this can be found in the fact that patients with damage to the ventromedial prefrontal cortex ("PFC") are unlikely to exhibit emotional responses to stimuli, whereas those patients with dorsolateral PFC damage appear to have problems in cognitive processing of tasks that do not seem to evoke emotional processing (for example, the Wisconsin Card Sorting Task).[64] Interestingly, both types of reasoning seem to be necessary for optimal problem solving. Because of cognitive limitations, it is not the case that one should always use either cognitive processing (or more colloquially "logic") or affective processing (more colloquially "emotion"), the latter of which has been conditioned by evolutionary pressures to punish or reward behavior. Because of these conflicts, and the lack of inherent superiority of one mechanism over the other, there needs to be some mechanism to resolve this conflict. A significant amount of research now focuses on how this resolution occurs. The goal of this research is to discover how we maintain cognitive control over our state of mind as well as our actions.[65]

One region of the brain that is clearly involved in cognitive conflict resolution is the anterior cingulate cortex ("ACC"). This area is currently thought to be involved in registering a conflict between regions. Some researchers argue that after a conflict is recognized, various areas of the PFC, including the ACC, also become active and the choice of regions activated depends on the cognitive requirements of the problem presented.[66] In addi-

63. Per E. Roland & Karl Zilles, *Structural Division and Functional Fields in the Human Cerebral Cortex*, 26 BRAIN RES. REVIEWS 87 (1998).

64. GAZZANIGA ET AL., *supra* note 55, at 506. The Wisconsin Card Sorting Task involves sorting cards that have objects on them that vary along three dimensions: shape, color, and number. The cards are to be sorted according to a method determined by the experimenter, but not explicitly told to the subjects. The subjects learn the rule by trial an error, via feedback from the experimenter as to whether a particularly sorting is in accord with the rule or if it violates it. *Id.*

65. James K. Rilling et al., *A Neural Basis for Social Cooperation*, 35 NEURON 395 (2002).

66. J.B. Ponchon et al., *The Neural System That Bridges Reward and Cognition in Humans: An fMRI study*, 99 PNAS 5669, 5673 (2002).

tion, the context in which the problem is presented may have a significant impact on the mechanism used to address the problem.[67]

Some economists have argued that even self-destructive behaviors can best be modeled as conscious rational choices.[68] Others, generally psychologists, argue that these behaviors are the result of lack of control; these individuals did not set out to become criminals or addicts, but the behaviors are the results of cognitive or emotional deficits. Both sides have significant evidence for their arguments. To the extent these discoveries are conscious, it is clear that the law can affect them. However, to the extent that they are unconscious, the ability of law to alter them is less clear.

The extent to which processes are conscious or unconscious may have a significant effect on legal questions. For example, to what extent should law attempt to alter unconscious processing in addition to conscious processes? To what extent can it affect these processes? This is a question that future research will have to answer.

2. The Effects of Personal Interaction

There has been a fair amount of research that analyzes the different brain regions activated by personal as opposed to impersonal interactions. One example of this is research on the neural mechanisms involved in the reactions of subjects to standard hypothetical moral dilemmas that involve personal and impersonal decision making.[69] While using fMRI technology to image the brains of the subjects, Greene et al. asked a number of questions, including a thought experiment regarding how the subjects would respond if faced with a moral dilemma with the following facts. Subjects are told that a train is coming down a track, and, if they do nothing, the train will hit a car on the track and five people will be killed, but, alternatively, if they press a button, the train will be diverted to a side track and only one person will be killed.[70] As has been known for many years, most people report that they would choose to press the button.[71] Interestingly, the response is quite different if a similar, but slightly different, situation is presented. In this second moral dilemma, the subjects would have to push the person next to them onto the track, killing them.[72] Here, most people

67. Janet Metcalfe & Walter Mischel, *A Hot/Cool-System Analysis of Delay of Gratification: Dynamics of Willpower*, 106 PSYCH REV. 3 (1999).

68. Becker et al., *supra* note 51, at 239.

69. *See* Joshua D. Greene et al., *An fMRI Investigation of Emotional Engagement in Moral Judgment*, 293 SCIENCE 2105 (2001).

70. *Id.*

71. *Id.* at 2106.

72. *Id.* at 2105.

answer they would not do that. The study shows that the parts of the brain that are actively involved in the decision to push the person are similar to those involved in emotions, such as fear and grief.[73] The decision to flip the switch, which would also result in killing a human, involved far fewer emotional reactions. In particular, the areas more likely to be active in personal moral dilemmas—such as pushing the person on to the tracks—were areas of the medial frontal gyrus, the posterior cingulate gyrus, and the bilateral superior temporal sulcus ("STS").[74] These areas are normally involved in social-emotional processing.[75] The nonmoral or impersonal dilemmas (e.g., switching the train track) tend to activate areas in the dorsolateral PFC and the parietal cortex (normally involved in calculation and executive function).[76] For those subjects who did decide to push the person next to them, one might argue that "logic" or cognitive processes prevailed over "emotion." Interestingly, those who did decide to push the other person took significantly longer in making this decision than those who chose not to push the other person (a difference of 5 seconds for those who would not push the person versus 6.75 for those who would). There was very little difference between the brain activation or decision time between impersonal moral dilemmas and nonmoral dilemmas (less than half a second). This would tend to indicate that the more impersonal the decision becomes, the more we can be "rational" or rather adopt what one might argue are socially optimal decision-making mechanisms. This suggests that certain types of moral decision making involves a fair amount of social thinking and invokes notions of positive and negative reciprocity, and personalization. Other more recent experiments confirm that the regions of the brain involved in moral processing are also the same regions used in social cognition.[77] One recent study by Jorge Moll et al. attempted to separate out the regions involved in moral judgments as opposed to those involved in emotional processing.[78] They found that moral situations differentially activated the STS and the OFC.[79] One key distinction between this experiment and the experiment by Greene et al. is that the subjects

73. *Id.* at 2107.

74. Joshua Greene & Jonathan Haidt, *How (and Where) Does Moral Judgment Work?*, 6 TRENDS IN COGNITIVE SCIENCES 517, 519 (2002).

75. *Id.*

76. *Id.*; Stanislas Dehaene, *The Organization of Brain Activations in Number Comparison: Event-Related Potentials and the Additive-Factors Method*, 8 J. COGNITIVE NEUROSCIENCE 47 (1996).

77. Jorge Moll et al., *The Neural Correlates of Moral Sensitivity: A Functional Magnetic Resonance Imaging Investigation of Basic and Moral Emotions*, 22 J. NEUROSCIENCE 2730, 2733 (2002).

78. Jorge Moll et al., *Functional Networks in Emotional Moral and Nonmoral Social Judgments*, 16 NEUROIMAGE 696 (2002).

79. *Id.* at 700.

were merely reacting to stimuli rather than making decisions about how to behave.

Consistent with these experiments as well as many others, it appears that the method of reasoning changes depending on the nature of the problem presented. This may have many applications for our understanding of law and the legal system. For example, in attempting to understand how juries reach the decisions they do, we can see that individuals may make socially optimal choices more when they keep the subject of the decision at a distance. If the decision is personalized in some way, this can in and of itself alter the decision. Of course, more work needs to be done to fully understand what kinds of situations result in personalization and the precise way in which reasoning processes differ between personal and impersonal situations. To the extent that the conclusions from these experiments bear up in further experiments, society may have an interest in depersonalizing problems that are presented to decision makers. In addition, objectivity may require more than simply not being related or not having a direct stake in the outcome. These and other experiments suggest that even having to face someone is enough to invoke personal and social triggers.[80] This research may also indicate that society needs to frame interactions so that the "personalization" will result in actions that are in accord with what is socially optimal, rather than being in conflict with it (e.g., attempt to utilize personalization to obtain optimal cooperation). One hopes that further research in this area will examine how individuals personalize problems when the stakes to personalization are high.

It appears that moral reasoning is spread across many neural mechanisms[81] and how any particular problem is resolved appears to depend on the interaction of these mechanisms. It appears that any moral problem may be approached in a very different manner than another that may appear to be similar to our conscious minds. Therefore, an important line of future research is the attempt to understand the mechanisms by which problems are interpreted. In particular, how problems become perceived as social and how at other times problems can be interpreted as "simply" cognitive problems is one of the key questions for understanding the impact of law on behavior.

80. *See* John O. Ledyard, *Public Goods: A Survey of Experimental Research*, *in* THE HANDBOOK OF EXPERIMENTAL ECONOMICS, *supra* note 29, at 111.

81. William D. Casebeer & Patricia S. Churchland, *The Neural Mechanisms of Moral Cognition: A Multiple-Aspect Approach to Moral Judgment and Decision-Making*, 18 BIOLOGY & PHILOSOPHY 169, 174–86 (2003).

3. The Ultimatum Game

Many of the mechanisms used by the brain to deal with situations of cognitive conflict are illustrated in the ultimatum game. The neurological studies of how players in this game make decisions illustrate the mechanisms the brain uses to resolve the conflict between deciding whether to accept money (something generally desired), but, at the same time, also accepting what individuals are likely to view as an unfair bargain, or choosing to reject the money and enforce fairness. Similar mechanisms appear to be invoked whenever actions against the subject's immediate self-interest are chosen.

The ultimatum game is a two-player game in which the first player is given a stake and is told to divide it between the two players. After the first player has decided, the second player can then choose to accept the division or to reject the division. If the second player rejects the division, both players get nothing. It is fairly common for the proposed division to be a 50/50 split. However, many times the first player will propose an unfair split (e.g., a 90/10 split). These latter splits are commonly rejected by the second player.[82]

One experiment on the neural mechanisms involved in the decision of the second players found that those players who rejected "unfair" offers had much higher activation in the insula cortex than those who accepted these offers. On the other hand, those who accepted these offers had higher activations in the dorsolateral prefrontal cortex. In both types of subjects, the ACC was also significantly active.[83]

As the Sanfey et al. experiment shows, different brain regions (such as the insula and the dorsolateral prefrontal cortex) seem to embody different thought processes.[84] To some extent, the ACC seems to moderate between these different regions depending on the situation. The neurological mechanism would appear to be more consistent with an ecological approach to rationality. That is, individuals have a variety of mechanisms that adopt different approaches to problems. These approaches are then mediated by neural mechanisms, which are likely based on reward signaling. Therefore it should not come as a surprise that individuals adopt seemingly "irrational" strategies to problems.

82. *See* CAMERER, *supra* note 42, at 8–12.

83. *See generally* Sanfey et al., *supra* note 21, at 1756 (explaining the neural mechanisms involved with regard to inequality aversion).

84. *Id.* at 1758.

4. Ecological Rationality and Economics

Neurological research seems to indicate that the brain has different decision-making mechanisms that often lead to different decisions. This would not seem to be in accord with constructivist notions of rationality, which imply only one type of decision-making mechanism. Far from being problematic, this actually allows for a more ecological approach to decision making, where different approaches are considered before the best solution is selected. This kind of decision making works best when not every decision concerns life or death, but rather merely increases or decreases the likelihood of survival in some understandable way. If it is not possible to guess ahead of time which mode will necessarily yield the correct decision, it may be more productive to be able to generate a variety of different strategies and later determine which might work best.

In addition, ecological rationality is not necessarily antithetical to many of the predictions of traditional economics. A large portion of standard economic results are of the type referred to as comparative static results, i.e., what will occur at equilibrium. Ecological rationality models indicate that the comparative statics of boundedly rational actors will often result in efficient outcomes, in fact possibly more efficient than standard economic theory predicts. It might very well be the case that these models depart from the predictions of constructivist rationality more in the dynamics of how the predicted equilibria arise, rather than in the characteristics of these equilibria.

When problems are particularly hard for individuals to solve, we often create institutions to deal with these problems. Consider for example the institutional forms of corporations or governments. These do not really exist as physical entities but are merely mechanisms that we have adopted in order to more easily account for certain actions given our cognitive mechanisms. These are examples of institutions that were developed by a relatively small number of individuals but have now been adopted worldwide.

CONCLUSION

Current empirical research on decision making indicates that there are important ways in which individuals do not conform to standard economic models. However, it would be a mistake to conclude from this that individuals should be labeled irrational. In fact, the research indicates that individuals who are behaving irrationally under constructivist notions of rationality are often behaving consistently with ecological notions of rationality. However, much more work needs to be done to understand the precise nature of human decision making. This research needs to consider the contexts, both environmental and neurological, in which these decisions are made.